

Coconut shell activated charcoal as a counter electrode for a novel dye-sensitized solar cell

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Introduction

Dye sensitization is an attractive technique in fabricating wide band gap semiconductor solar cells (Fernando *et al.*, 2000). p-CuI is an attractive colloidal semiconductor due to its large surface area and which can absorb many number of dye molecules. The band gap of p-CuI was reported as 3.0eV (Hemachandra *et al.*, 2013) but sensitization of suitable dyes on p-CuI semiconductors can enhance the light absorption.

Porous carbon materials such as activated carbon have attracted in these recent years because of its low cost and high availability. Coconut shell activated charcoal serves as a counter electrode (CE) in photo-electrochemical cells (PEC). Another important factor in PEC is CE separate and transfer photogenerated carriers to the external circuit through I/I_3 redox electrolyte.

Sandwiched type PEC fabricated with Cu/ p-CuI/ dye/ (I/I_3) redox solution/ CAC/ ITO according to the figure 1. The dye octadecyl rhodamine- C_{18} (Rh- C_{18}) and dioctadecyl merocyanine (C_{18} -Mero- C_{18}) monolayers were deposited by the Langmuir-Blodgett (LB) technique. A remarkable stability and photocurrent enhancement was observed in the device.

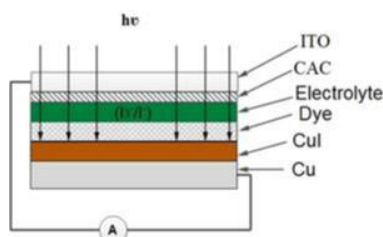


Figure 01: Schematic structure of devices

Methodology

Well cleaned Cu plates (1cm x 3cm) were immersed in an acetonitrile solution of 1 M containing 5mg of dissolved CuI powder. The thickness of the CuI layer was controlled with the immersed time (Fernando *et al.*, 2000). The dyes were deposited according to the technique of LB films (Fernando *et al.*, 1994; Fernando *et al.*, 1995). After the dyes were deposited, 150nm thin layer of CAC powder (particle size ≈ 150 nm and the surface area of $\approx 1457.1 \text{ m}^2/\text{g}$) was applied on top of the dye by doctor blade method to fabricate Cu/p-CuI/dye/CAC. ITO glass plate was placed on Cu/p-CuI/dye/CAC, where an acetonitrile solution containing 10^{-2} M KI and 10^{-4} M I_2 was used as the liquid electrolyte

Results and Discussions

From the diffuse reflectance spectra for the photo electrodes of on Cu/p-CuI/ Rh-C₁₈, Cu/p-CuI/ C₁₈-Mero-C₁₈ and Cu/p-CuI/ Rh-C₁₈+ C₁₈-Mero-C₁₈. p-CuI absorption edge was observed at the wave length around 420nm in all photo electrodes. Clear absorption peaks were observed at 561nm, 574nm and 573nm for the above photo electrodes respectively.

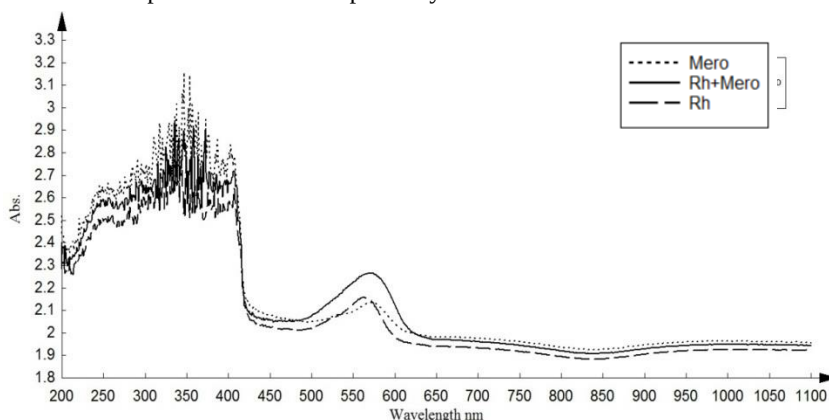


Figure 02: Diffuse Reflectance Spectra

The main photo-current generation processes associated with the device can be summarized from the following processes.

1. Excitation of the dye molecules at p-CuI/Dye interface

$$\text{Dye} + h\nu \rightarrow \text{Dye}^*$$
2. Generation of the photogenerated charge carriers

$$\text{Dye}^* \rightarrow \text{Dye}^- + h(\text{VB} - \text{p-CuI})$$
3. Photogenerated charge carrier separation

$$2 \text{Dye}^- + \text{I}_3^- \rightarrow 2 \text{Dye} + 3 \text{I}^-$$
4. Electron transfer from electron acceptor to ITO

$$3 \text{I}^- + \text{ITO} \rightarrow \text{I}_3 + 2e (\text{ITO CB} - \text{SnO}_2)$$

After introducing the CAC layer in the PEC, the reaction (4) is modified in an interesting way as follows.

5. Electron transfer from electron acceptor to ITO through CAC

$$3 \text{I}^- + \text{CAC} \rightarrow 2 \text{CAC}^- + \text{I}_3^-$$

$$2 \text{CAC}^- \rightarrow \text{CAC} + 2e (\text{ITO CB} - \text{SnO}_2)$$

The quantum efficiency at 573nm against the number of dye monolayer for the devices of on Cu/p-CuI/ Rh-C₁₈/(I⁻/I₃⁻)/CAC/ITO, Cu/p-CuI/ C₁₈-Mero-C₁₈/(I⁻/I₃⁻)/CAC/ITO and Cu/p-CuI/ Rh-C₁₈+C₁₈-Mero-C₁₈/(I⁻/I₃⁻)/CAC/ITO. The quantum efficiency initially increases with the number of monolayers of the dye. The maximum quantum efficiency was observed on the PECs fabricated with 5 monolayers of Rh-C₁₈ or C₁₈-Mero-C₁₈. But with the double dye PEC, the maximum quantum efficiency of 35% was observed for 10 monolayers.

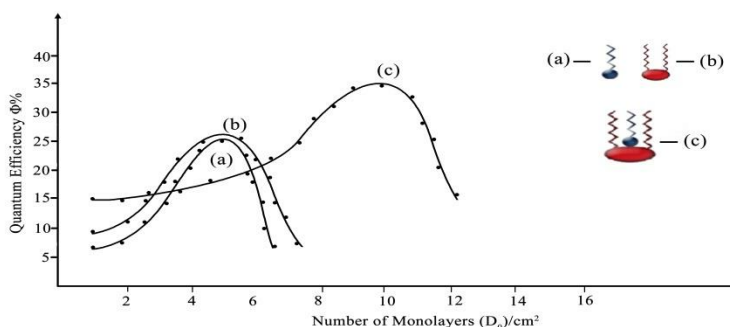


Figure 03: Variation of the photocurrent quantum efficiency (Φ %) at 573 nm against the number of dye monolayers. (a) Cu/p-CuI/R-C18/(I-/I₃)/CAC/ITO, (b) Cu/p-CuI/M-2C18/(I-/I₃)/CAC/ITO, (c) Cu/p-CuI/R-C18+ M-2C18/(I-/I₃)/CAC/ITO.

Conclusion

Cu/p-CuI/dye/(I/I₃) redox solution/CAC/ITO PEC device was fabricated and a remarkable photocurrent enhancement was observed after introducing the double dye and a thin layer of 150nm thick CAC. The porous of CAC efficiently acted as a hole mediation layer for I/I₃ redox couple and consequently efficient photo charge separation occurred.

References

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